

JEOL 6400 Process Sheet for Electron Beam Lithography

Huber, W., 06-07-00
revised Edelstein, M., 03-16-06

Super Users: Monica Edelstein, x2078
Neil Zimmerman, x5887

Specialized training is required for use of this tool. Contact Gerard Henein
for information.

Once trained, if unsure about anything, contact a super user.

Keyboard Commands:

PF1	Clears text off right screen
PF2	Adjust SEM parameters (3 different screens)
PF3	Adjust Frame Integration Parameters
PF10	Lens Clear

Arrow keys shuttle cursor around screen
Number keys toggle screens (e.g. "1" for screen 1)
+ or - to increase or decrease a parameter
"BREAK" to toggle scale bar on either screen
"ESC" to toggle between left and right screens

Lithography Operation

- 1) Ramp Filament Page 2
- 2) **Wait > 30 minutes to warm up and stabilize beam.**
- 3) Optimize Gun Shift & Tilt Page 3
- 4) Load Sample Page 5
- 5) Position Sample and Adjust Focus Page 7
- 6) Focus & Minimize Astigmatism Page 9
- 7) Run NPGS Software NPGS Manual
- 8) Unload Sample Page 11
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Ramp Filament

Starting Conditions

Filament Current	~1.5 A (FILA button illuminated)
Emission Current	0 uA (FILA button not illuminated)
Beam Current	0 pA (using PCD)
Bias	~7 (depends on filament position and age)
ACCEL Button:	Illuminated
Accelerating Voltage Pot	0 kV
Ion Pump Power Switch	ON
Ion Pump Pressure	$< 5 \times 10^{-5}$ Pa
EBL Control Box Switch	SEM
PCD Switch	ON (Illuminated)
Beam Blanking Switch	OFF

- 1) Look at previous **Filament Current** setting in log book (~ 2.3 to 2.6 A)
- 2) Using **Accelerating Voltage** pot, increase voltage from 0 kV to desired amount (usually 40 kV).
- 3) Using either **Probe Current** pot or keyboard, adjust **CL COARSE** to 6.
- 4) Over ~ 60 sec, slowly increase **Filament Current** to ~2.2 Amps and monitor **Beam Current** on Ammeter.
 - Check to see that ion pump pressure is $< 9 \times 10^{-5}$ Pa.
- 5) Slowly (~ 30 sec) increase **Filament Current** pot until **Beam Current** begins to saturate; ~ 2.3 A (old filament) to ~ 2.55 A (new filament). Saturation will occur at same or a slightly lower **Filament Current** than previous settings. Be sure to not increase **Filament Current** beyond previous saturation value for more than several seconds.
 - At saturation, **Emission Current** ~ 55-65 uA and will decrease by ~ 5 uA over ~ 1 hour until thermally stabilized. (Dependent upon filament age)
 - Examine log book for previous values.
 - Check to see that ion pump pressure is $< 9 \times 10^{-5}$ Pa.
- 6) Measured **Beam Current** will stabilize after ~ 30 minutes for electron beam lithography.

Optimize Gun Shift & Tilt

Starting Conditions

Filament Current	Saturated (See Ramp Filament)
Emission Current	~ 50-60 uA
ACCEL Button:	Illuminated
CL Coarse	See Below
CL Fine	Same as previous value in log book
EBL Control Box Switch	SEM
PCD Switch	ON (Illuminated)
Beam Blanker Switch	OFF

Usually, only minor adjustments are necessary to beam alignment from day to day. Initially, perform the following procedure using only steps 1 and 6-10. If satisfactory, you are done. If unsatisfactory, or if the filament is new, or if the instrument has just been brought back up from a down state (planned or unplanned), it may be necessary to perform the entire procedure.

- 1) Ensure that filament is thermally stable (minimum of 15 min after saturation)
- 2) **CL Coarse = 10:**
 - Toggle **SHIFT** button into dark position to enable gun tilts.
 - Optimize **Beam Current** (measured with Ammeter) by adjusting the **X** and **Y** pots adjacent to the **SHIFT** button.
- 3) **CL Coarse = 5:**
 - Toggle **SHIFT** button into illuminated position to enable gun shifts.
 - Optimize **Beam Current** (measured with Ammeter) by adjusting the **X** and **Y** pots adjacent to the **SHIFT** button.
- 4) **CL Coarse = 13:**
 - Toggle **SHIFT** Button into dark position.
 - Optimize **Beam Current** (measured with Ammeter) by adjusting the **X** and **Y** pots adjacent to the **SHIFT** button.
- 5) **CL Coarse = 2:**
 - Toggle **SHIFT** Button into illuminated position.
 - Optimize **Beam Current** (measured with Ammeter) by adjusting the **X** and **Y** pots adjacent to the **SHIFT** button.
- 6) **CL Coarse = 14:**
 - Toggle **SHIFT** Button into dark position.
 - Optimize **Beam Current** (measured with Ammeter) by adjusting the **X** and **Y** pots adjacent to the **SHIFT** button.
- 7) **CL Coarse = 1:**

- Toggle **SHIFT** Button into illuminated position.
 - Optimize **Beam Current** (measured with Ammeter) by adjusting the **X** and **Y** pots adjacent to the **SHIFT** button.
- 8) **CL Coarse** = 14:
- Toggle **SHIFT** Button into dark position.
 - Optimize **Beam Current** (measured with Ammeter) by adjusting the **X** and **Y** pots adjacent to the **SHIFT** button.
- Optimized **Beam Current** should now be within ~10% of previous log book value for **CL Coarse** = 14.
- 9) If **Beam Current** is appreciably below log book value, or the current does not continuously increase as **CL Coarse** is moved incrementally from 14 to 1, set **Gun Shifts** and **Tilts** to log book values and repeat above procedure.
- 10) Adjust **CL Fine** to desired **Beam Current** with **PCD** button illuminated.
[10.6 pA (PCD) ~ 10.0 pA (actual)].

Load Sample:

Detector	OFF
Collector	OFF
Stage Height (z)	39 mm
Horizontal (x)	25 mm
Stage Rotation	0
Tilt	0°
PCD Switch	ON (Illuminated)
V1B	CLOSED

- 1) Put on pair of fresh latex gloves.
- 2) Mount sample on desired holder.
- 3) Screw sample holder on transfer rod until (pinkie) finger tight.
- 4) Press button V7 on the vacuum control panel to close the gun chamber valve. This isolates the gun chamber during sample exchange.
- 5) Slide lucite plate fully towards sample holder.
- 6) Press lucite plate on opening of load lock and press button on gate valve.
- 7) Wait approximately 2 minutes for load lock to pump down.
- 8) When pressure is low enough:
 - Fairly loud 'clunk' is audible from pneumatic valve opening.
 - Button on gate valve will be dark.
- 9) Open gate valve by rotating knob ~90° CCW and then pulling out ~ 3".
- 10) Check to see that ion pump pressure is $< 5 \times 10^{-5}$ Pa.
- 11) While looking through Lucite plate, slowly (2 seconds) slide sample holder onto stage.
 - Check to see that ion pump pressure is $< 5 \times 10^{-5}$ Pa.
 - Check to see that holder is properly mounted on stage.
- 12) Rotate rod CCW ~ 10 turns
- 13) While looking at sample holder, slowly retract rod fully back.
 - Check to see if sample begins to slide back
 - If so, check stage x, z, tilt, and rotation, then try again.

- 14) With rod fully retracted, push gate valve knob fully towards valve and then rotate CW $\sim 90^\circ$.
- 15) Press button on gate valve, remove rod and store on plastic holder.
- 16) Press button V7 on the vacuum control panel to open the gun chamber valve.

Position Sample and Adjust Focus

- 1) Using **CL Coarse** ~ 9-12, **Focus** on large features near edge of sample (e.g. particles or contact pad). Carefully move stage height to desired working distance and focus again. **Warning:** Never allow the sample working distance to be less than 5 mm at the risk of destroying the backscatter detector. Choose an aperture (usually 4) and press “wobble” to check aperture centering. Adjust aperture x/y as necessary to obtain an image that does not “swing” as it goes through focus. If astigmatism is observed, make corrections and re-focus.
- 2) Move the sample such that an edge is centered on the viewing screen and minimize apparent sample rotation by adjusting **Stage Rotation** and/or **Scan Rotation**.

Steps 3-9 assume that you will align your e-beam pattern to four alignment marks patterned (usually by photolithography and metallization) at the corners of the e-beam litho area. If alignment marks are not used, use CL Coarse ~ 12-14, and choose a spot near the e-beam litho area, but not so near that you will expose the writing area to the beam. If a particle is visible, focus on it, then move slightly to a smooth area and skip to steps 2-7 on page 9, then return to this page to complete steps 10-12 and step 14.

- 3) Using **CL Coarse** ~ 12-14, **Magnification** ~ 400-800x, translate stage until upper left alignment mark is visible on right side of screen. Be careful not to expose writing area with beam.
- 4) Using **CL Coarse** ~ 12, focus upper on left alignment mark @ **Magnification** ~ 30,000x .
- 5) **Focus & minimize Astigmatism** (see page 9) on upper left alignment mark. Record **Focus** setting in notebook
- 6) At **Magnification** ~ 2,500x, translate stage to upper right alignment mark. Be careful not to expose writing area with beam.
- 7) At **Magnification** ~ 2,500x, translate stage to lower right alignment mark. Be careful not to expose writing area with beam.
- 8) **Focus & minimize Astigmatism** (see page 9) on lower right alignment mark.
- 9) Adjust **Focus** to average of upper left and lower right alignment mark values.
- 10) Move **Beam Blanker** switch to EXT position.
- 11) Decrease **Magnification** to desired amount (generally, 200x to 1000x).

- 12) Using micrometers, move stage until center of writing area is near center of viewing area.
- 13) Move **Beam Blanker** switch to OFF position and quickly check whether alignment marks are close to dots drawn on screen.
- 14) Using keyboard, set Scan Speed = 640, Brightness & Contrast = 190. Move **Beam Blanker** switch to EXT position, and **EBL Control Box** Switch to NPGS. Run desired NPGS program. (See NPGS manual).

Focus & Minimize Astigmatism (Necessary for < 150 nm lithography)

Check that:

Filament Current	Saturated & Stable (See Ramp Filament)
Emission Current	~ 50-60 uA (FILA button dark)
EBL Control Box Switch	SEM
PCD Switch	OFF
Beam Blanker Switch	OFF

- 1) Using **CL Coarse** ~ 12, **Magnification** ~ 20,000x, shift image using (**Shift X & Y** pots w/**POSN** light not illuminated) until edge of alignment mark is in view and adjust **Focus**.
- 2) Using **CL Coarse** ~ 12, **Magnification** = 300,000x, insure that beam is not on top of metal alignment mark. Switch to **Spot Mode** (Using **MODE** button) and observe Ammeter for ~ 30 seconds.
 - If current decreases after ~ 3 seconds, **Focus** is nearly optimized.
 - If current slowly increases over the entire 30 seconds, sample is somewhat out of **Focus**.
 - If current does not change over the entire 30 seconds, sample is severely out of **Focus**. Go back to step 1.
- 3) Switch back to **TV Mode** using **PIC** button and adjust **Focus** until contamination dot is visible.
- 4) Using desired **Beam Current** (Usually 10.0 pA => **CL Coarse** ~ 14), **Magnification** = 300,000x locate previous contamination dot and refocus. Move slightly to a fresh area. Switch to **Spot Mode** and observe Ammeter for ~ 30 seconds.
 - If current decreases after ~ 3 seconds, **Focus** is nearly optimized.
 - If current slowly increases over the entire 30 seconds, sample is somewhat out of **Focus**.
- 5) Switch back to **TV Mode** and adjust **Focus** until contamination dot is in focus. Adjust **Astig X** and **Y** and **Focus** until sharpest image of contamination dot is obtained. When optimized, feature will no longer appear to rotate when moving in and out of focus (it will still shift slightly however). If astigmatism cannot be removed, check aperture centering ("wobble"). If aperture is centered, reduce magnification to ~50kx, and press PF10 (lens clear). If there is hysteresis in the lens, the image will shift and go out of focus, so find the contamination dot(s) on the screen and re-focus. Press PF10 again. If the image remains nearly in focus and does not shift, recheck aperture centering, then adjust **Focus** and **Astig X and Y**.

- 6) Move slightly to a fresh area. Switch back to **Spot Mode** and observe Ammeter. When reading has dropped ~ 5%, switch back to TV Mode and optimize **Astig X** and **Y** and **Focus**.
- 7) If contamination dot remains circular both in and out of focus, astigmatism has been minimized. If not, go back to step 6.

Unload Sample:

Detector	OFF
Collector	OFF
Stage Height (z)	39 mm
Horizontal (x)	25 mm
Stage Rotation	0
Tilt	0°
PCD Switch	ON (Illuminated)
V1B	CLOSED

- 1) Slide lucite plate fully towards tip of rod.
- 2) Press button V7 on the vacuum control panel to close the gun chamber valve. This isolates the gun chamber during sample exchange.
- 3) Press lucite plate on opening of load lock and press button on gate valve.
- 4) Wait approximately 2 minutes for load lock to pump down.
- 5) When pressure is low enough:
 - Fairly loud 'clunk' is audible from pneumatic valve opening.
 - Button on gate valve will be dark.
- 6) Open gate valve by rotating knob ~90° CCW and then pulling out ~ 3".
- 7) Check to see that ion pump pressure is $< 5 \times 10^{-5}$ Pa.
- 8) While looking through Lucite plate, slowly (2 seconds) slide rod towards sample holder.
 - Check to see that ion pump pressure is $< 5 \times 10^{-5}$ Pa.
 - Check to see that tip of rod guides into threaded hole in sample holder.
- 9) Rotate rod CW until (pinkie) finger tight.
Be careful not to overtighten!
- 10) While looking at sample holder, slowly retract sample fully back.
 - Check to see that sample slides off stage with rod, otherwise check stage x, z, tilt, and rotation, then try again.
- 11) Push gate valve knob fully towards valve and then rotate CW ~ 90°.
- 12) Press button on gate valve. When button illuminates, remove rod.
- 13) Press button V7 on the vacuum control panel to open the gun chamber valve.

- 14) Remove sample holder from rod assembly and store assembly on plastic holder.
- 15) Remove sample from holder.

Park Microscope

Filament Current	~1.4 A (FILA button illuminated)
Emission Current	0 uA (FILA button not illuminated)
Beam Current	0 pA (using PCD)
Bias	~7
Accelerating Voltage Button:	Illuminated
Accelerating Voltage	0 kV
Magnification	300,000 x
Scan Speed	Slow (e.g. 2)
Brightness	< 170
Contrast	< 170
Idle Console Conditions	
Stage Height (z)	39 mm
Horizontal (x)	25 mm
Stage Rotation	0
Tilt	0°
Ion Pump Power Switch	ON
Ion Pump Pressure	< 5 x 10 ⁻⁵ Pa
EBL Control Box Switch	SEM
PCD Switch	ON (Illuminated)
Beam Blanker Switch	OFF
Correct valve lights illuminated	ON (Green): V2, V7, V1A, V1C, LV2 ON (Amber): LV4, LV 5 OFF: V3, V4, V5, V1B, LV1, LV3

Red Toggle Switch V1B Illuminated

Text cleared on both screens (i.e. 'PF1' and 'BREAK')

Cursor on left screen

EBL Control Box Switch in 'SEM' position

Sample Removed From Chamber